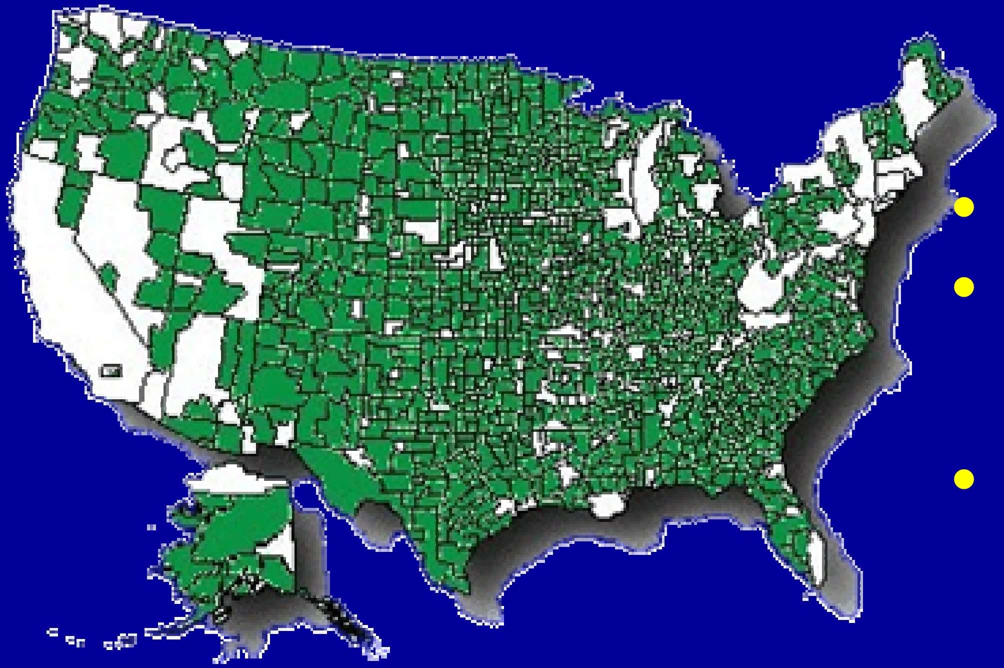
Making a Difference With

CRN

COOPERATIVE RESEARCH NETWORK

A SERVICE OF THE NATIONAL RURAL ELECTRIC COOPERATIVE ASSOCIATION

Co-op Basics



- Customer owned
- Serve 34 million consumers in 46 states → 75 percent of nation's area
- 2.3 million miles of line is close to half of nation's total

Moreover ...

- Growth rate <u>twice</u> that of IOU Electrics
- Six customers per line-mile ...vs... 33 for IOU
- Co-ops view DP as needed solution; not a "*Problem*"

CRN's Four Technology Units

- Automation, Telecommunications, and Information Technology
- Distribution Operations
- Marketing and Energy Services
- Power Supply

Co-op Tech Roadmap

- Ensure technology investments are aligned with cooperative business network strategies
- Provide framework for building R&D partnerships with other organizations
- Expand the (EPRI) electricity roadmap, which supports electric industry but does not address challenges unique to co-ops
- Align co-ops' interests with national interests

Projects Support the Roadmap

- MultiSpeak
- Demonstrations (fuel cells and microturbines)
- Technology Surveillance
- CRN Learning Center
- Renewable Energy Evaluations
- Key Account Tools and Technology
- Transmission Reliability

Research Meets DG Needs

- Understand the technology options
- Explore what your customers want
- Evaluate options for DG vs. grid services
- Demonstrate most attractive DG technology
- Establish reasonable business cases

DG Interconnection Tool Kit

- Business and Contract Guide for Interconnection, and Customer Guidelines for Interconnection
- Model Interconnection Application and two Model Interconnection Contracts
- DG Rates Manual
- Technical Application Guide

Broad Range of Programs

CRN Microturbine Demo Unit installed at Chugach / AVEC

Chugach EA's 1-MW PAFC Installation
at Anchorage Post Office

DG Technologies Overview

Characteristics	Size (kW)	Current Installed Cost ($/kW)	Electricity Cost (¢/kWh)*	Year Commercial	Applications
Internal Combustion Engine	50 to 5,000	$200 to $800	5.5¢ to 10.0¢	Available	Back-up Power, Peak Reduction
Wind Turbine	50 to 2,000	$1,000 to $1,500	5.5¢ to 15.0¢	Available	Green Power, Remote Locations
Microturbine	25 to 75	$1,500 to $2,500	10.0¢ to 15.0¢	Available	Peak Reduction, Back-up Power
Fuel Cell	5 to 2,000	$3,000 to $4,500	10.0¢ to 15.0¢	Commercial sizes available	Power Quality, Baseload, Premium Power
Solar Cell	1 to 100	$1,500 to $6,500	15.0¢ to 20.0¢	Available	Stock watering, Communications, Grid Independent

* assuming fuel at $5.50/natural gas

Cooperative Research Network, Winter 2001

NRECA/DOE Wind Outreach

- 3-year program (2002-2004)
- Tasks
  - Regional Workshops
    - Summer 2002 – Upper MidWest
    - Fall 2002 - Nebraska
  - Information dissemination
  - Technical support

Regional Workshops

- Provide insight in developing resources and wind system performance
- Responsive to the needs of the region
- Share cooperative experiences with wind power - both positive and negative
- Identify technical analysis and assistance activities

Wind Assessment: Lessons Learned

- Good siting and good wind data – acquired by site-specific wind measurement – are critical to the success of a wind project
- Utility management must be committed to the project –development, maintenance, and marketing
- There is a learning curve for both utilities (wind technology, warranty issues, etc.) and vendors (utility operations, requests for down payment, etc.)
- Not everything is going to work the first time – expect there to be a process of debugging the equipment
- Why wind? – satisfy customer needs, improve customer relationships, positive community relations tool, local economic development benefits

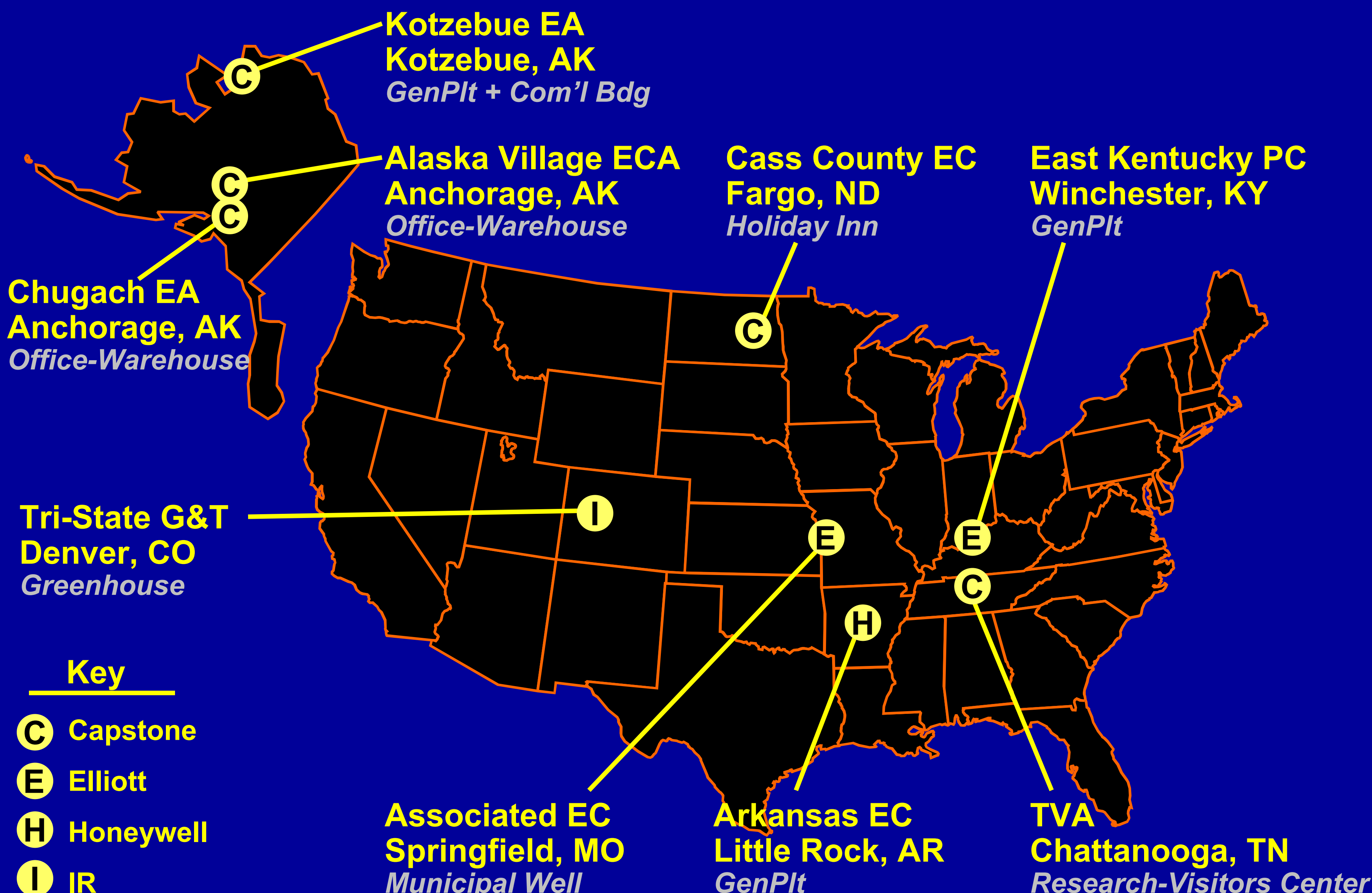
Information Needs

- Interconnection requirements
- Distribution system impacts/system protection/power quality
- Resource assessment
- Technical & economic feasibility
- Reliability, durability, longevity
- Installation and O&M costs
- Green power programs
- Project planning
- Market issues and transmission
- Intermittency
- Environmental issues
- Small wind turbines

Microturbine Program Objectives

- Collect test and operation information on installation and performance by NRECA participants
- Identify developmental needs re: permitting, interconnection and building code compliance
- Identify developmental needs re: technology, maintenance and operation
- Provide technology baseline to benchmark future improvements

Co-op Participants



Demonstration Features

- Sound cross section of manufacturers
  - 5 Capstones
  - 2 Elliotts
  - 1 Honeywell
  - 1 Ingersoll-Rand
- Multiple fuels
  - Low pressure natural gas
  - Fuel Oil
  - Propane
- Thermal recovery
- Grid-Independent and Grid-Parallel operation
- Baseload and simulation of remote grid dispatch
- Simulation of SCADA integration

Gas Fired Capstone at Chugach Site

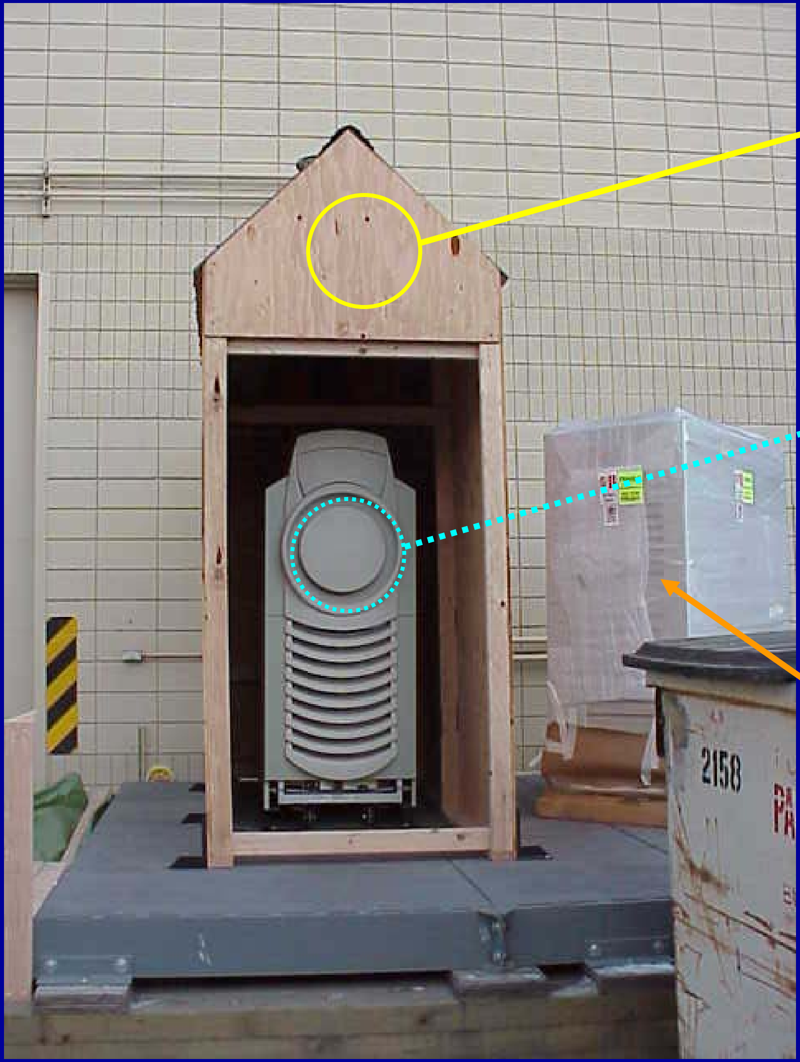
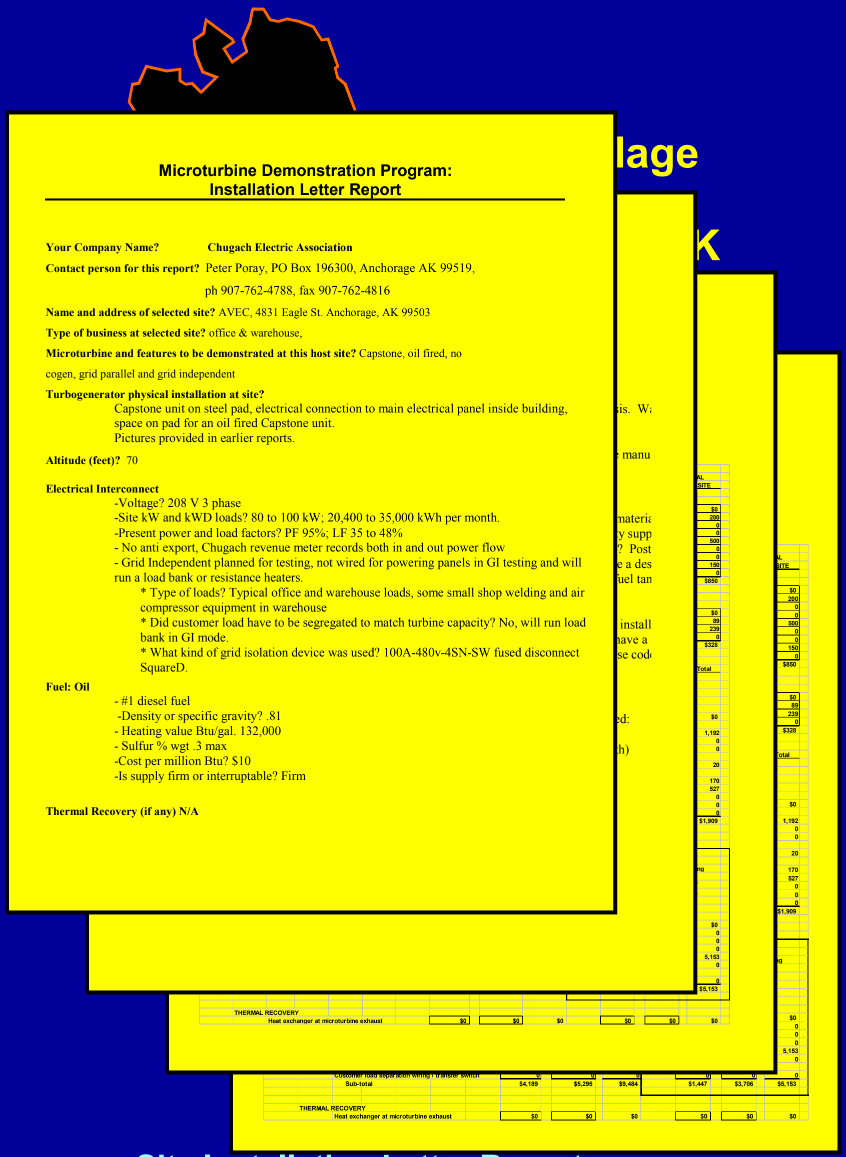


Photo courtesy of Chugach Electric Association
Anchorage, AK

- Wooden enclosure halved troublesome tone noise to nearby residences
- Capstone now has a a silencer retrofit kit for inside the micro-turbine cabinet

Oil fired Capstone awaiting installation

Typical Co-op Reporting (Chugach)


Microturbine Demonstration Program:
Installation Letter Report

Your Company Name? **Chugach Electric Association**
Contact person for this report? Peter Poray, PO Box 196300, Anchorage AK 99519,
ph 907-762-4788, fax 907-762-4816
Name and address of selected site? AVEC, 4831 Eagle St. Anchorage, AK 99503
Type of business at selected site? office & warehouse,
Microturbine and features to be demonstrated at this host site? Capstone, oil fired, no cogen, grid parallel and grid independent
Turbogenerator physical installation at site?
Capstone unit on steel pad, electrical connection to main electrical panel inside building, space on pad for an oil fired Capstone unit.
Pictures provided in earlier reports.
Altitude (feet)? 70
Electrical Interconnect
-Voltage? 208 V 3 phase
-Site kW and kWD loads? 80 to 100 kW; 20,400 to 35,000 kWh per month.
-Present power and load factors? PF 95%; LF 35 to 48%
- No anti export, Chugach revenue meter records both in and out power flow
- Grid Independent planned for testing, not wired for powering panels in GI testing and will run a load bank or resistance heaters.
* Type of loads? Typical office and warehouse loads, some small shop welding and air compressor equipment in warehouse
* Did customer load have to be segregated to match turbine capacity? No, will run load bank in GI mode.
* What kind of grid isolation device was used? 100A-480v-4SN-SW fused disconnect SquareD.
Fuel: Oil
- #1 diesel fuel
-Density or specific gravity? .81
- Heating value Btu/gal. 132,000
- Sulfur % wgt .3 max
-Cost per million Btu? $10
-Is supply firm or interruptable? Firm

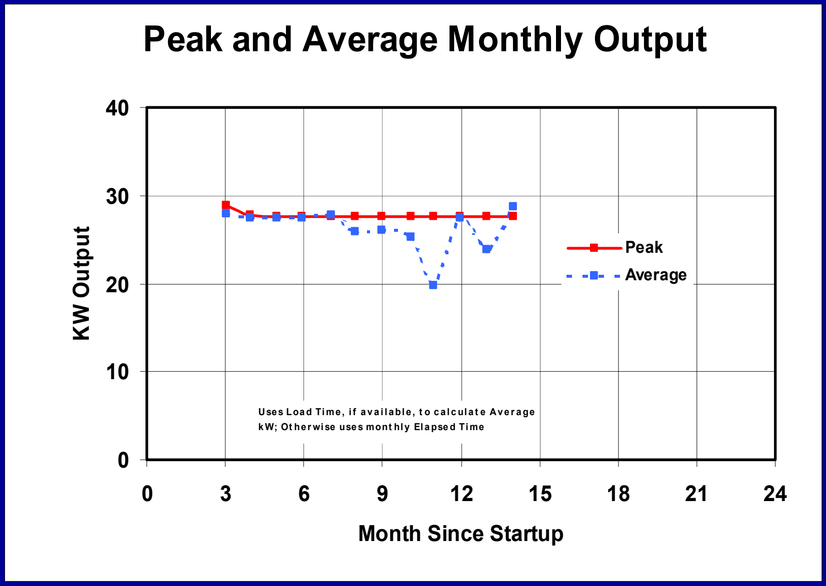
Thermal Recovery (if any) N/A

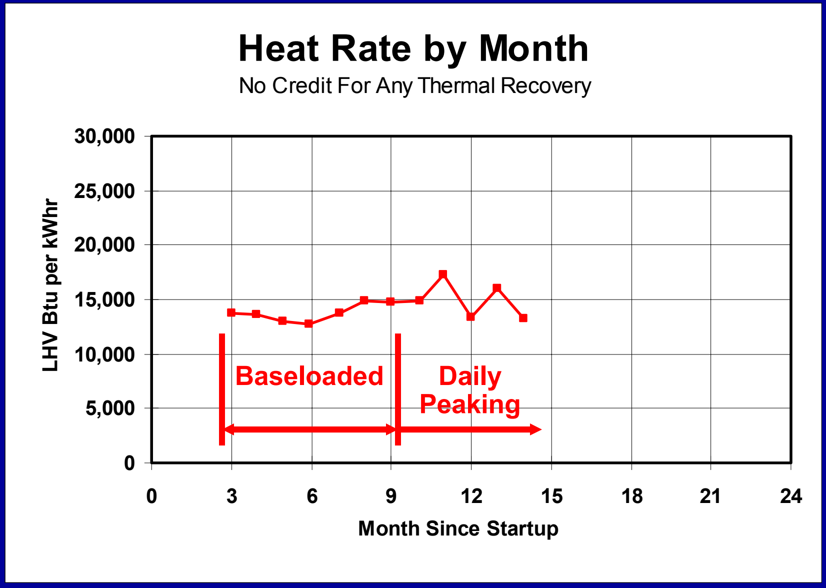
Site Installation Letter Report
and Cost Spreadsheets

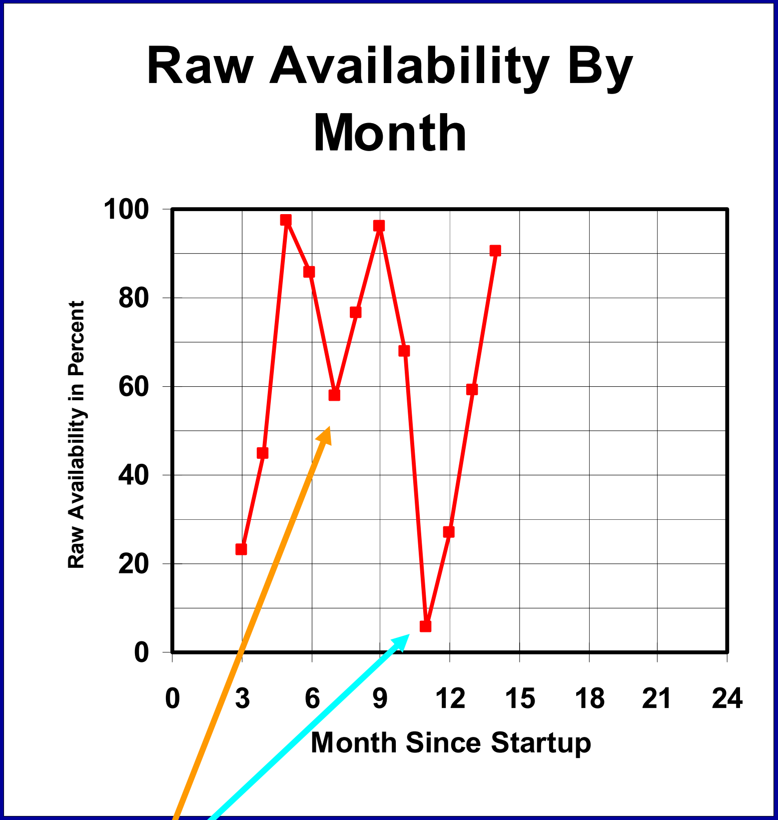
- **Interconnect**
  - 130 feet; 480 to 208 3-Ph via transformer
  - 170 feet to new 15 psig NG, New oil tank
- **Costs: Demo and Com'l**

	Natural Gas	Fuel Oil
Actual Demonstration:		
Engineering	$4,670	$10,200
Permitting	3,300	560
Fuel	2,950	11,230
Electrical	9,500	9,500
Thermal Recovery	NA	NA
Total	$20,420	$31,490
Projected if Full Commercial unit at customer site:	$8,250	$18,120

Typical Co-op Reporting (Chugach)







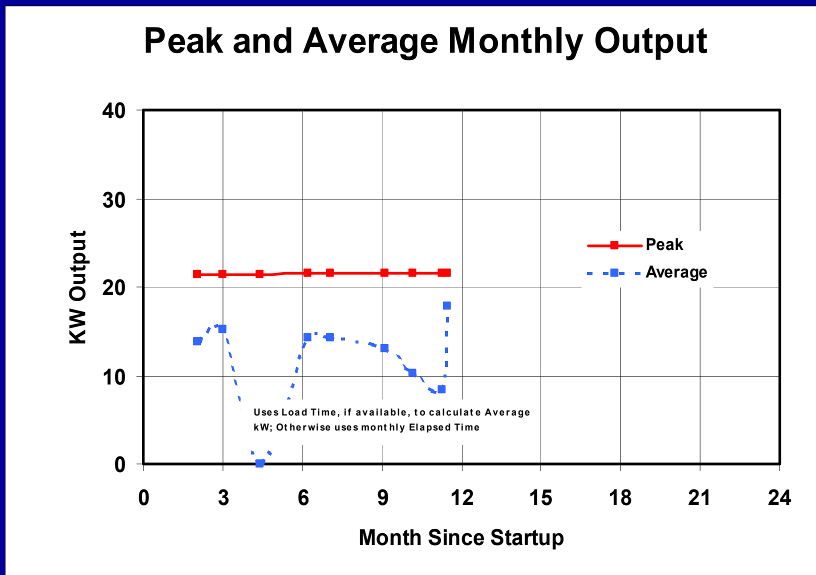
Reduced availabilities due to replacements of Rotary Fuel Compressor, etc. New air bearing design should enhance availability.

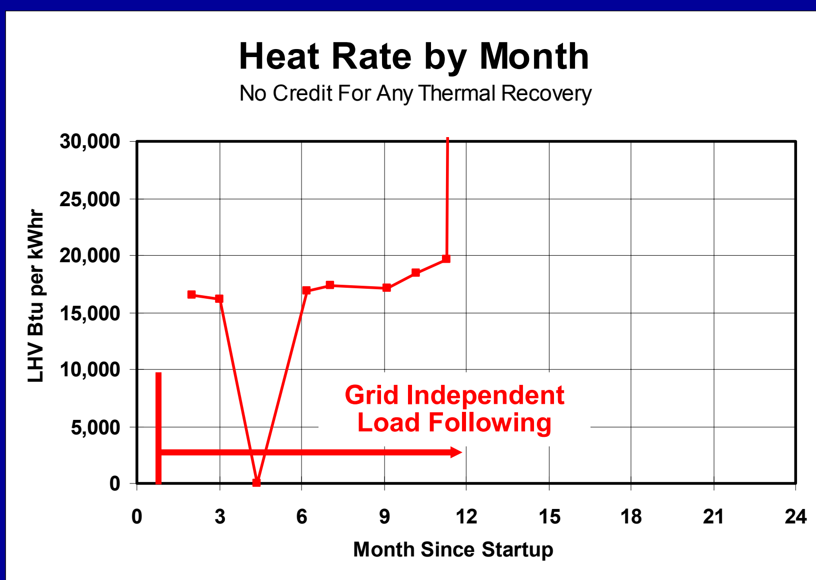
Gas Fired Capstone at Cass County Site

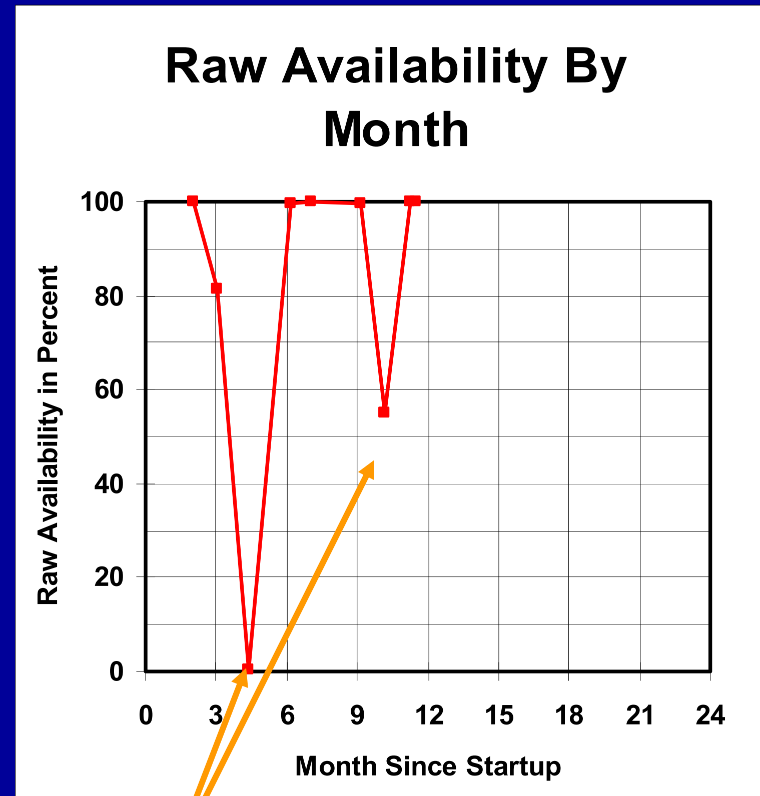
CRN Demo Unit installed at Cass County

- Located at Holiday Inn in North Dakota
- Natural Gas at 11 psig - Runs Grid Independent
- Electric output powers an electric water heater!
- Thermal recovery is for additional water heating

Typical Co-op Reporting (Cass County)







Reduced availabilities due to replacements of Rotary Fuel Compressor, etc.

Technology Bottom Line

- No endemic technology failures to date (microturbine power assembly, recuperator, etc).
- Efficiencies about as represented.
- Capstone perhaps most “commercial” but all manufacturers beset by peripheral issues.
- Areas where design enhancements needed:
  - Fuel gas compressor likely to remain a high-maintenance item and energy consumer (~5 to 7% of kWh)
  - Limited motor start capability constrains Grid Independent use
  - Inverters may need more “hardening” relative to grid

Typical Equipment and Installation Costs

Doubling the Size: Reduces Equipment Cost per kW by 20%

Reduces Installation Cost Component per kW by 35%

How Does Cost Stackup?

Cost to Customer (Cents / kWh)

	Rural Co-op	IOU Electric	Customer Owned
Peaking @ 1,500 Hours per year			
Owning Cost	14.3	20.3	24.6 to 34.2
\$6 /MilBtu NatGas* + 1.5¢ Maint	8.6	8.6	8.6
Total	22.9	28.9	33.2 to 42.8
BaseLoad @ 95% avail = 8,322 Hours per year			
Owning Cost	2.6	3.7	4.4 to 6.2
\$6 /MilBtu NatGas* + 1.5¢ Maint	8.6	8.6	8.6
Total	11.2	12.3	13.0 to 14.8

* \$1.20 / gallon Fuel Oil is equivalent to \$8.65 per million Btu Natural Gas …and… \$1.10 per gallon Propane is equivalent to \$12 per million Btu Natural Gas

Basis: Excludes cogeneration credit which at full thermal recovery could reduce busbar costs 2.5 ¢/kWh for gas price of \$6.00 per MilBtu.

\$1,100 / kW equipment plus \$275 / kW installation — *10-Year equipment life*

14,200 HHV Btu / kWh heat rate — *Maintenance at 1.5 cents per kWhr*

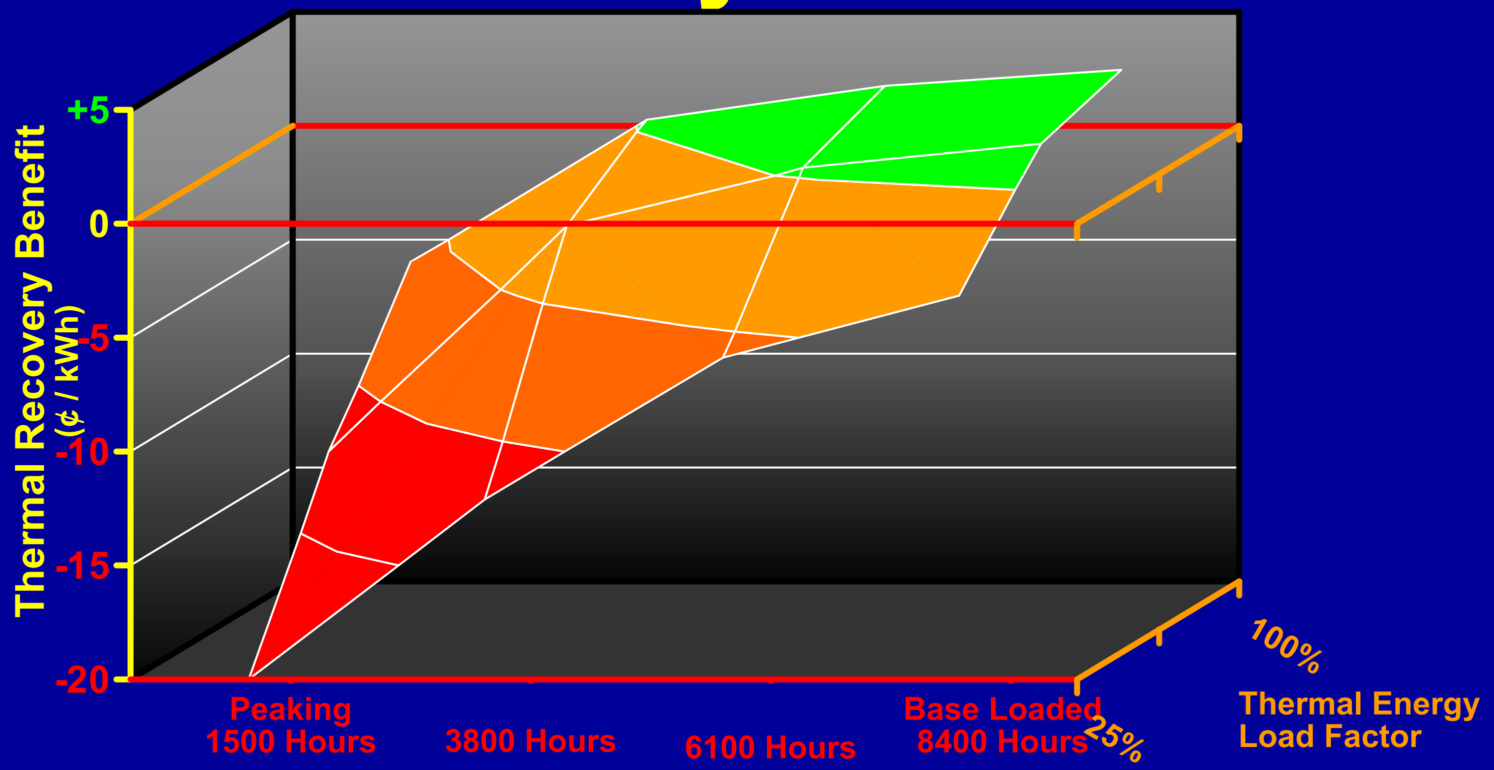
Debt is at 9% were applicable — *Utility ROE is 18%*

Customer Owned ROE is 25% → 3.3 YrPayback — *Range is w w/o debt financing*

7-Year MACRS for FIT where applicable — *No Investment Tax Credit*

Combined FIT + StateIncomeTax rate is 41.5%

Thermal Recovery Attractiveness



- **Unless electric thermal displaced, cost effective thermal recovery requires base loaded operation and maximum thermal use.** ⇨ **Applicable sites limited!**

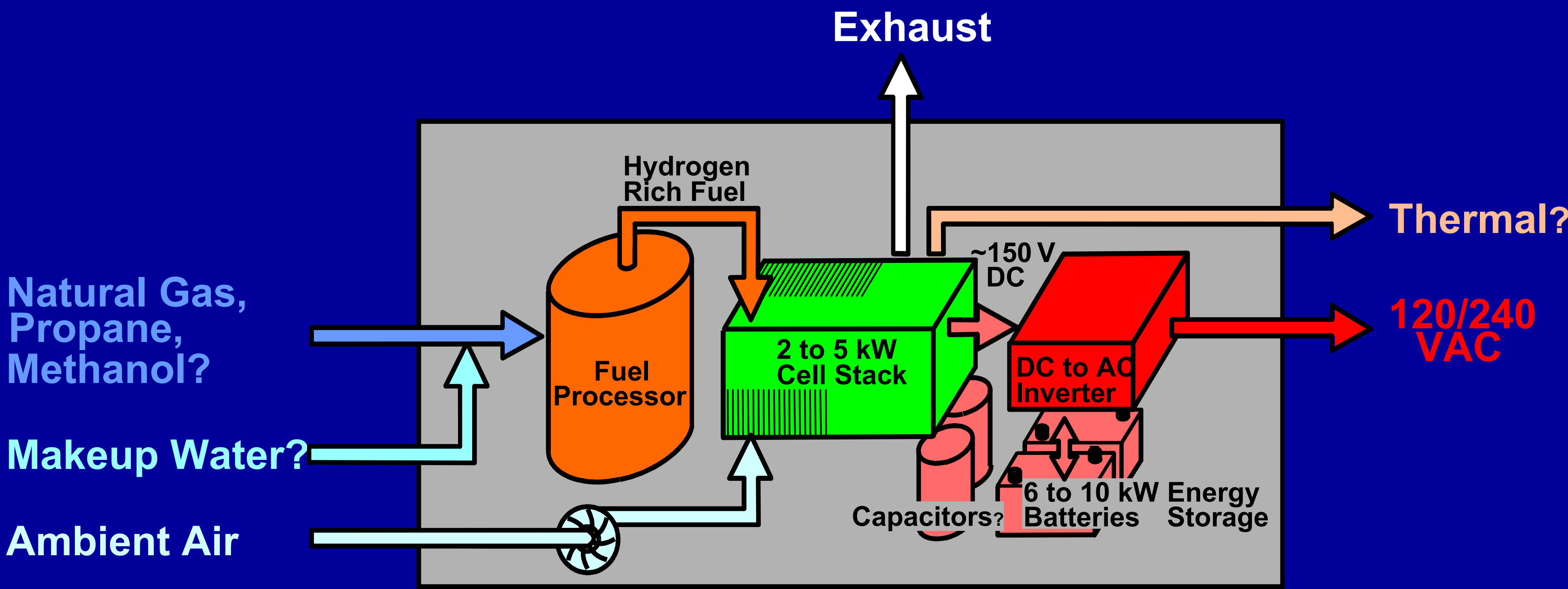
- **Thermal recovery Installation Cost can quickly spiral if every last Btu chased.**

Basis: ***$25,000 cost to install 330,000 Btu/Hour Thermal Recovery at a 60 kW microturbine site***
Customer owns thermal recovery equipment and requires a 3.3 year payback
Displaced thermal use was fueled by $6 natural gas at a 75 percent combustion efficiency

RFC Demonstration Objectives

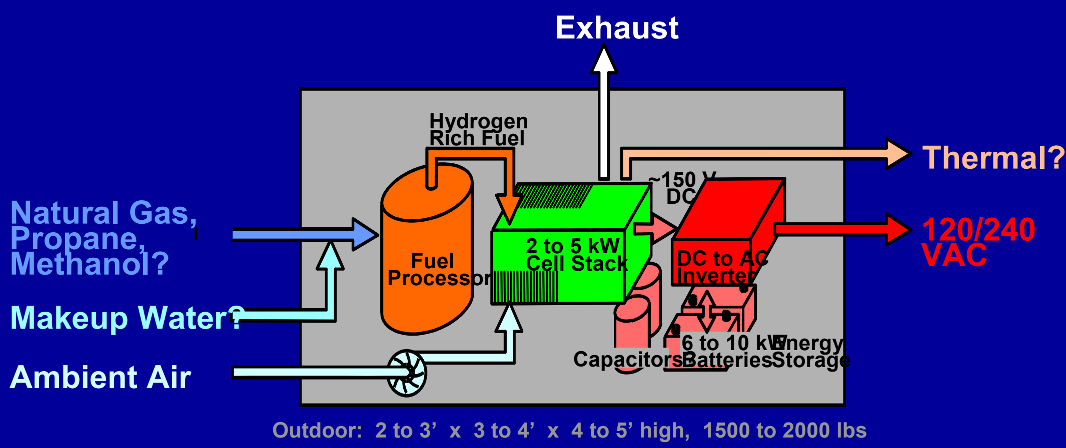
- Ascertain key near-term / long-term DG benefits
- Identify and resolve critical DG implementation barriers
- Build solid foundation for co-op DG
- Benchmark Residential Fuel Cell (RFC) technology for further effort

Typical Demonstration Unit



Outdoor: 2 to 3' x 3 to 4' x 4 to 5' high, 1500 to 2000 lbs

Basic Issues



Issue is NOT will RFC's work but how long will they work . . . and . . . Price / Markets?

- Life and aging of cell stack
- Reformer life and response
- Inverter load following
- Reliability and maintainability

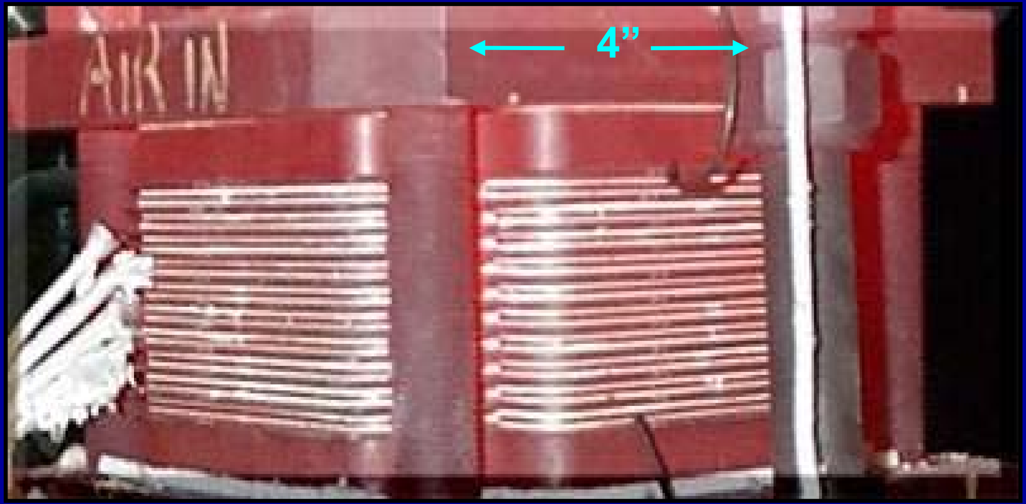
- Can Mfgr's deliver on production-cost curve
- Application economics vs typical customer size
- Market Profile

Co-op Participants

Program Summary

- 8 Co-op Participants
- **Multiple Manufacturers** (Final Spectrum depends on Co-op Selections)

MANUFACTURER	DEMONSTRATION CAPABILITY PROFILE	
H Power	4Q 2001	Early production, Energy Co-Opportunity
Inter'nl Fuel Cells	1Q 2002	United Technology, Significant Reformer and FC tech
Plug Power	2Q 2002	Substantial GE and joint venture funding, NG-GP First
Avista	3Q 2002	Modular hot swappable cell substacks and inverters
Others		



Global Thermoelectric 1 kW Planar Cell Stack running at 1400°F

Typical RFC Early Entrance Markets

- **Off-grid homes and other off-grid uses**
  - Line extension or single phase service line is $15,000 to $20,000+ per mile
  - Difficult, or impossible, to secure right-of-ways in parts of country
- **Home office users**
  - Avoid snow or ice storm interruptions (Cost-effective digital satellite now available for telephone and www)
  - Avoid hurricane outages
- **Partial power supply to outage sensitive office and other customers**
- **High income technophiles or "greens"**
- **"Green" or upscale housing developers**

Already Accomplished

RFC DP Application Analysis → Demo Handbook

"the present RFC Bible"

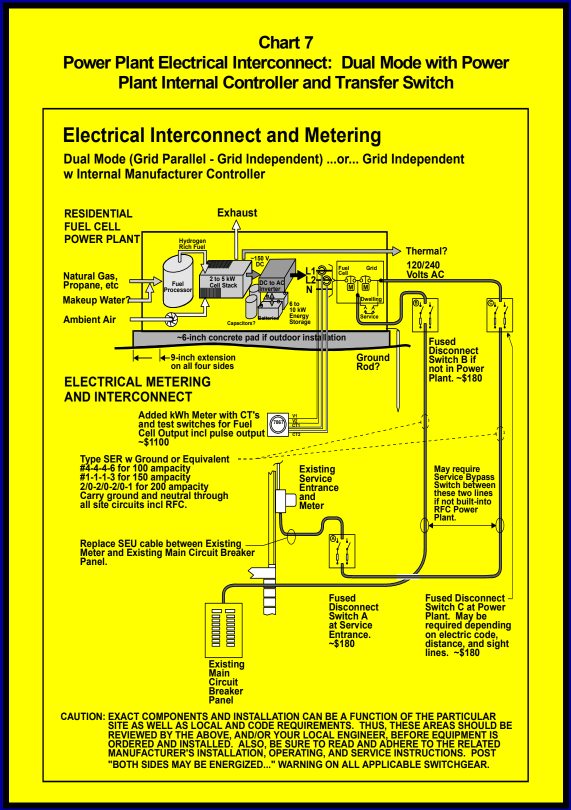
- Demonstration planning, installation, operation
- Identify and manage application barriers including: electrical / fuel / water / thermal recovery / etc.

  Includes Electrical Interconnect:
  - Types, analysis, and Issues (GP GI DualMode)
  - Interconnect and PQ verification procedures

- Thermal recovery (CHP) applications, integration, and benefits
- Data collection / instrumentation protocols
- Assess market and application issues

Already Accomplished (cont'd)

Typical Issues and Barriers Identified and Being Worked



- Grid Parallel export of power at night
- Remote disconnect / SCADA need
- Disconnects and location re code
- Inverter-to-Dwelling fault clearing
- Motor start capability
- etc
- Required fuel pressure vs codes
- Propane odorant level and variation
- Thermal recovery RFC loop vs safety/ codes
- etc

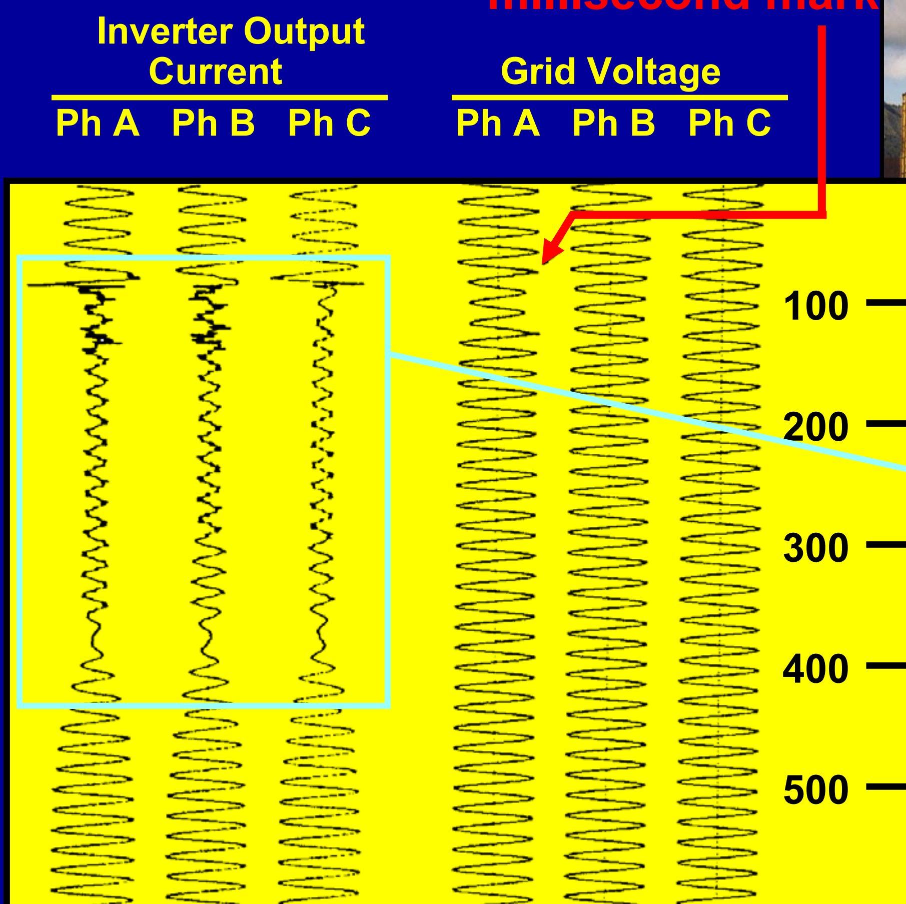
Interconnect Issues

- Islanding
  - Compare manufacturers' specs with co-op requirements
  - Perform validation testing
  - Monitor inverter performances
- General Issues
  - Near-term: Unlikely to be significant
  - Long-term: Significant only for high RFC saturations and/or "help the grid" operations

Fuel Cell Experience

Over 200 ONSI 200 kW phosphoric-acid fuel cells worldwide logged millions of hours of reliable grid interconnection

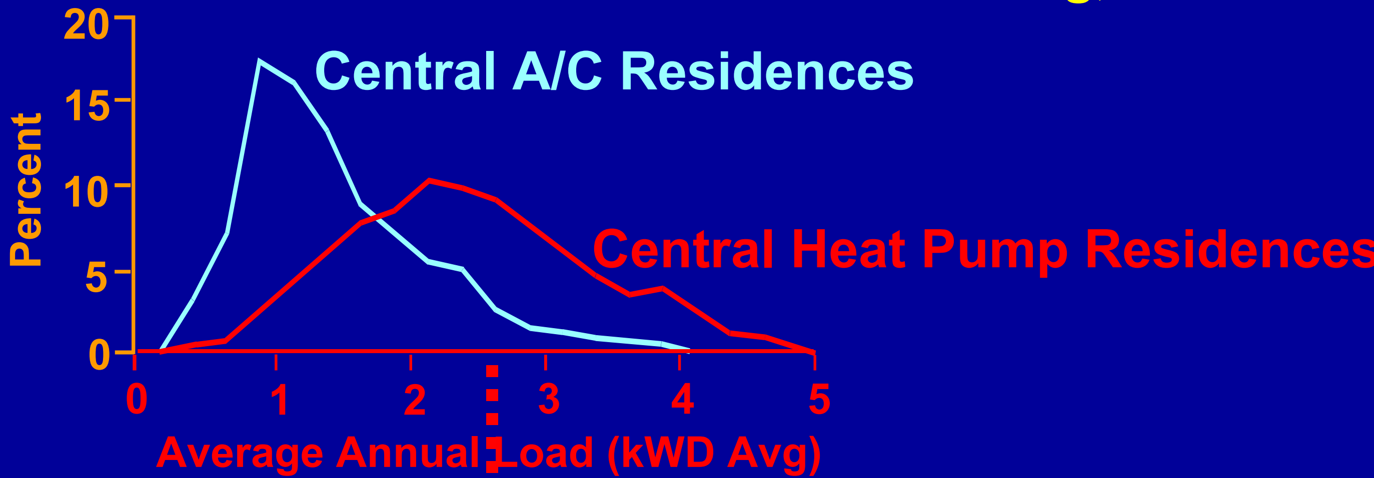
Grid Upset at 70 millisecond mark



Inverter interrupts and stops grid-following power export, waits 350 milliseconds to allow the grid to return to normal

Economics Best Cases

- $4,000 Installed Cost
- 10-Year Life @ 9 percent Cost of Capital $625 /yr
- Service Calls @ $200 each $200 /yr
- $5 Natural Gas = 5.2 ¢; $1.00/gal Propane = 11.1 ¢
- Per each 25% hot water heating, reduce fuel 15 percent



Cents Per kWh = Capital + Fuel

$$= \frac{9.4}{\text{kWD Avg}} + 5.2\ ¢$$

Residential Heat Pump Profile

HEAT PUMP SATURATION IN SINGLE FAMILY DETACHED DWELLINGS (HOMES)

Census Division	City	Suburban	Town	Rural	Weighted Avg All Four	Composite of Town plus Rural
New England	0.0	3.5	0.0	1.9	1.4	0.9
Middle Atlantic	0.0	5.4	1.9	4.3	3.5	3.4
East North Central	2.0	0.0	3.7	6.7	2.7	5.5
West North Central	0.0	4.4	0.8	12.0	3.6	5.1
South Atlantic	30.9	41.7	15.1	19.0	28.1	17.5
East South Central	13.7	25.5	8.6	30.1	21.5	24.3
West South Central	5.0	14.0	3.0	11.9	6.7	6.0
Mountain	7.9	10.1	7.4	7.4	8.0	7.4
Pacific	0.9	7.4	4.6	6.5	3.5	5.5
Composite	8.0	13.6	4.9	12.7	9.7	9.1

Saturation of ELECTRIC APPLIANCES AND OTHER APPLICABLE ELEMENTS in the above TOWN PLUS RURAL locations for the above SINGLE FAMILY DWELLINGS THAT USE HEAT PUMPS:

Electric Water Heating	90%
Electric Range	93%
Dishwasher	69%
Electric Dryer	95%
Well Pump	39%
Utility Gas Available	17%
Propane Used	7%

Courtesy NASA